

INTERIM

7N-89-CR

0 CIT

28268

P. 33

Various Roentgen Satellite (ROSAT)
Related Studies

NASA Grant NAG5-1724

Semiannual Report Nos. 4 and 5

For the Period 1 February 1993 through 31 January 1994

Principal Investigators
(See Attached)

N95-70604

Unclass

29/89 0028268

September 1994

Prepared for:

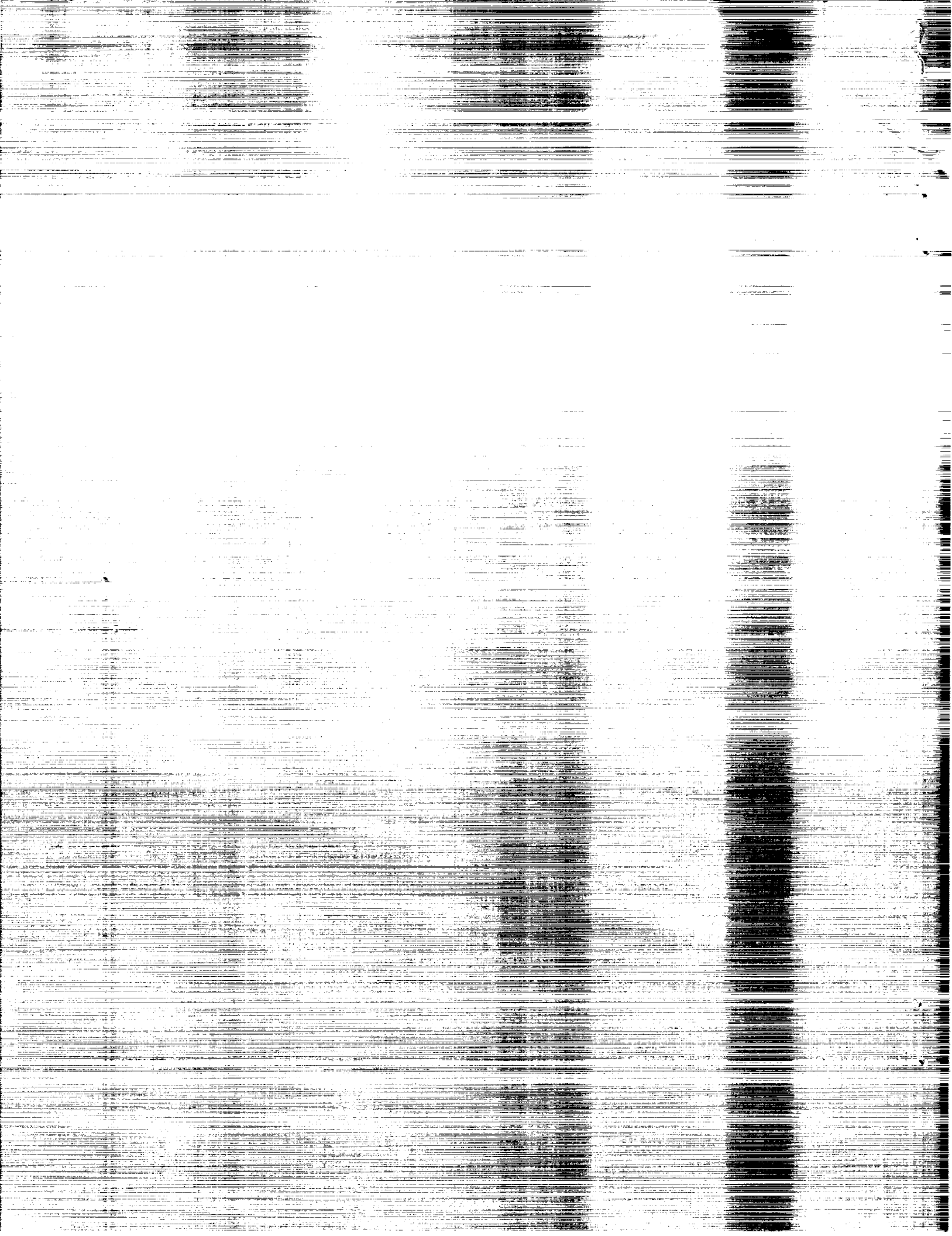
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

(NASA-CR-196979) VARIOUS ROENTGEN
SATELLITE (ROSAT) RELATED STUDIES
Semiannual Reports Nos. 4 and 5, 1
Feb. 1993 - 31 Jan. 1994
(Smithsonian Astrophysical
Observatory) 33 p

The NASA Technical Officer for this grant is Dr. Robert Petre, Code 666, Laboratory for High
Energy Astrophysics, Space Sciences Directorate, Goddard Space Flight Center, Greenbelt,
MD 20771.



Contents

1 X-ray Quiet Quasars & Quasar Spectra at the Peak of Evolution — B. Wilkes	1
1.1 Scientific Results:	1
1.1.1 Absorption:	1
1.1.2 The X-ray spectrum:	1
1.1.3 Spectral Energy Distributions (SEDs):	1
1.1.4 X-ray luminosity functions and evolution:	2
1.2 Publications:	2
2 Two ROSAT Investigations — D. Worrall	3
2.1 X-ray Observations of the Structures Causing Refractive Scintillation	3
2.2 Determination of the X-ray spectra of a complete sample of flat-spectrum radio sources	4
3 The Soft X-ray Spectra of AGN Discovered Via Their Hard X-ray Emission — D. Schwartz	4
4 ROSAT Selected Area Survey-Eridanus — S. Murray	4
5 Two ROSAT Investigations — J. Hughes	4
5.1 Observations of the Clusters of Galaxies A665 and A2218: Targets for Sunyaev-Zel Dovich Effect	4
5.2 Observations of Supernova Remnants N132D and E0102 in the Magellanic Clouds	4
6 X-ray Studies of Gravitational Lenses — E. Kellogg	5
7 Observations of the X-ray Triple 4U2129+47 — M. Garcia	5
8 X-ray Observations of Elliptical Galaxies with Strong Radio Continuum — D. Kim	5
9 X-ray Emission as a Tool to Study Galaxy Formation: The Case of MS 111.9-3754 - A. Wolter	5
10 Cooling Flows in Poor Clusters of Galaxies — L. David	6
11 X-ray Luminosity Functions for O-Type Stars — F.R. Harnden, Jr.	6
A PREPRINTS	7

1 X-ray Quiet Quasars & Quasar Spectra at the Peak of Evolution — B. Wilkes

PR 666-27536A&B

All outstanding ROSAT data have now been received and analysis is currently underway or completed. Multiwavelength follow-up (optical spectrophotometry, optical imaging, infra-red photometry and ultraviolet spectrophotometry) of these targets is also nearing completion. The remaining observations are expected to occur over the next couple of months and include 1 IUE spectrum, 6 optical spectra and IR and optical photometry of about 20 objects. The data in hand is currently being reduced ready for analysis. I summarize below the main results and the papers in which they are reported.

1.1 Scientific Results:

1.1.1 Absorption:

We have discovered that soft X-ray absorption is common in high luminosity, radio-loud quasars at high redshift. Current evidence suggests that it may be related to dense gas surrounding the quasar which also encloses the radio emission for the radio-loud objects. The radio-quiet objects show less absorption and look similar to their low-redshift counterparts.

Absorption is also present in two low-redshift quasars: 3c351 and 3c212. The former also shows strong ultraviolet, metal-line absorption whose properties are consistent with the X-ray absorber, which is warm. This is the first time that X-ray absorption has been linked to that at other wavelengths and opens up very exciting possibilities for study of absorption as the combination of ultraviolet and X-ray data allows us to place strong constraints on the physical conditions of the absorber. Such constraints have not been possible to date.

1.1.2 The X-ray spectrum:

The X-ray slope of quasars does not change significantly with redshift when the same rest frame energy range is considered.

In low-redshift objects, the slope (both mean and in individual objects) seen in the soft ROSAT PSPC energy band (0.1-2 keV) is steeper by about 0.5 in index than that observed at higher energies (eg. .2-3.5 keV, Einstein IPC). Since no sharp change in slope is seen, this implies that some curvature is present in the spectra. Currently strong constraints cannot be placed on the form of this curvature as there remain unresolved cross-calibration problems between the two detectors which are being investigated.

1.1.3 Spectral Energy Distributions (SEDs):

The X-ray slope and optical to X-ray ratio are correlated in our PG sample. This correlation implies that a hard X-ray component is present in varying strengths. The X-ray slope is

also correlated with a few emission lines properties , eg. [OIII] flux, Hbeta FWHM. The cause of these correlations is not immediately apparent. The correlations are being further investigated using a larger sample.

The IR-X-ray SEDs of a few low-redshift quasars have been compared with accretion disk and free-free models for the blue bump component. Neither model matches the data in their simplest form. Modifications to the accretion disk model, such as the inclusion of an electron-scattering atmosphere, are able to match the data better.

1.1.4 X-ray luminosity functions and evolution:

We have completed a mid-depth survey ($f > 2 \times 10^{14} \text{erg/s/cm}^2$) of the central regions of 20 PSPC fields. The survey contains 123 sources, 66 of which are confirmed quasars and 14 have strong, narrow emission lines. We derived the evolution rate to be steeper than that found in earlier X-ray surveys: $L \sim (1+z)^{3.2}$; and more in line with optical surveys, in which the power is typically 3.5. The narrow-line objects are potentially an important contributor at fainter X-ray luminosities which had not previously been recognized.

1.2 Publications:

We have prepared a number of papers which are in various stages of submission:

PKS0438-436: a high redshift quasar with strong X-ray absorption (B. J. Wilkes, M. Elvis, H. Tananbaum, J. C. McDowell and A. Lawrence) *Ap.J.Lett.*, **393**, L1

The ROSAT Spectrum of 3C351: A Warm Absorber in an X-ray ‘Quiet’ Quasar (F. Fiore, M. Elvis, S. Mathur, B.J. Wilkes and J. McDowell) *Ap.J.*, **415**, 129

X-ray Absorption toward the Red Quasar 3C212 (M. Elvis, F. Fiore, S. Mathur and B.J. Wilkes) *Ap.J.*, *in press*

Absorption in X-ray Spectra of High Redshift Quasars (M. Elvis, F. Fiore, B. Wilkes and J. McDowell) *Ap.J.*, **422**, 60

The Complex Optical to Soft X-ray Spectrum of Low-redshift, Radio-quiet Quasars. I: The X-ray Data. (F. Fiore, M. Elvis, J.C. McDowell, A. Siemiginowska, and B.J. Wilkes) *Ap.J.*, *in press*

The Complex Optical to Soft X-ray Spectrum of Low-redshift, Radio-quiet Quasars II: The Broad-band Spectral Energy Distributions. (Fabrizio Fiore, Martin Elvis, Aneta Siemiginowska, Belinda J. Wilkes, Jonathan C. McDowell and Smita Mathur) 1994 *Ap.J.*, *submitted*.

The X-ray and Ultra-violet Absorbing Outflow in 3c351 (S. Mathur, B. Wilkes, M. Elvis and F. Fiore) *Ap.J.*, *submitted*

The Soft X-ray Properties of a Complete Sample of Optically Selected Quasars. I. First Results. (A. Laor, F. Fiore, M. Elvis, B. Wilkes and J. McDowell) *Ap.J.*, *submitted*

Infrared to X-ray Spectral Energy Distributions of High Redshift Quasars. (J. Bechtold, M. Elvis, F. Fiore, O. Kuhn, R. Cutri, J. C. McDowell, M. Rieke, A. Szymińska and B.J. Wilkes) *A.J.*, *submitted*

X-ray Spectral Evolution of High-Redshift Quasars (J. Bechtold, M. Elvis, F. Fiore, O. Kuhn, R. Cutri, J.C. McDowell, A. Szymińska and B.J. Wilkes) *A.J.*, *submitted*

The Cambridge-Cambridge X-ray Serendipity Survey: I X-ray Luminous Galaxies. (B.J. Boyle, R.G. McMahon, B.J. Wilkes and M. Elvis) *MNRAS*, *submitted*

The Cambridge-Cambridge X-ray Serendipity Survey: II The Data (B.J. Boyle, R.G. McMahon, B.J. Wilkes and M. Elvis) *in preparation*

2 Two ROSAT Investigations — D. Worrall

This grant covers two ROSAT investigations for which Diana Worrall is responsible. The first, “X-ray observations of the structures causing refractive scintillation in radio-bright AGNs” involved two ROSAT observations of BL Lac objects made during AO1. The second, “Determination of the X-ray spectra of a complete sample of flat-spectrum radio sources” is a collaborative program with a group from the University of Tübingen, Germany, where we have successfully competed for ROSAT observing time out of the German time allocation (AO1 through AO3) and Diana Worrall has assisted in planning the program and interpreting the results. Only the AO1 work for this second program was supported by the subject grant NAG5-1724: the continuation of this program in AO2 and AO3 was supported by NAG5-1882.

2.1 X-ray Observations of the Structures Causing Refractive Scintillation

PR 666-27521A

During the reporting period, the ROSAT data for the two BL Lac objects were tested for spatial extent by comparing the radial profiles with the PSPC point-response function. No extension was found.

Mark Birkinshaw completed reduction of VLA data for the two sources and found one of them to be extended in the radio. Work continues on comparing the radio and X-ray images to search for radio/X-ray coincidences of weak features in the vicinity of the sources. However, this investigation does not seem very promising.

The reporting period saw the publication of our preliminary results in the volume “Sub-arcsecond Radio Astronomy”, (1993, eds. R.J. Davis and R.S. Booth, Cambridge University Press, Page 303); preprint attached.

Although our primary reason for observing the two BL Lac objects (to search for anomalies in the X-ray spectra and light curves, and for structural evidence of scattering sites) has not yielded interesting positive results, the two BL Lacs are from a very important sample: the first homogeneous, radio flux limited, sample of radio-selected BL Lac objects. We are collaborating with a multi-institutional team to compile and interpret the ROSAT results for

the complete sample. The first results from this study were reported in a paper by Sambruna et al. at the Nov 1993 ROSAT Science Symposium (preprint attached).

2.2 Determination of the X-ray spectra of a complete sample of flat-spectrum radio sources

PR 666-27521B

This reporting period saw the submission (in December) and acceptance (in February) of a refereed paper which reports the primary results from this project: "X-ray Spectra of a Complete Sample of Extragalactic Core-dominated Radio Sources", by Brunner, Lamer, Worrall, and Staubert, to appear in *Astronomy and Astrophysics* (copy attached). Work during this reporting period was covered by the follow-on grant for this project: NAG5-1882.

3 The Soft X-ray Spectra of AGN Discovered Via Their Hard X-ray Emission — D. Schwartz

PR 666-27504

No new input.

4 ROSAT Selected Area Survey-Eridanus — S. Murray

PR 666-27230

No new input.

5 Two ROSAT Investigations — J. Hughes

5.1 Observations of the Clusters of Galaxies A665 and A2218: Targets for Sunyaev-Zel Dovich Effect

PR 666-27231A

No new input.

5.2 Observations of Supernova Remnants N132D and E0102 in the Magellanic Clouds

PR 666-27231B

No new input.

6 X-ray Studies of Gravitational Lenses — E. Kellogg

PR 666-27541

We have made no progress on this project because we have not yet received enough data to allow a reasonable analysis. We intend to try to get some data from the public archive to supplement the 2000 sec of exposure we already have, which yielded only about 80 counts from the target.

7 Observations of the X-ray Triple 4U2129+47 — M. Garcia

PR 666-27539

Observations with the ROSAT HRI allow detection of weak x-ray flux from the low-mass x-ray binary (LMXB) 4U2129+47 during its current quiescent state. The quiescent luminosity is similar to that seen in several other quiescent LMXB containing neutron stars. The quiescent x-ray light curve may not show the eclipse seen when the source was in its high state, which may indicate that the enhanced vertical structure present in the disk during the high state has collapsed. This in turn may provide support for the idea that the vertical structure in LMXB accretion disks is a consequence of high x-ray luminosity. A comparison of the absorption of low energy x-rays due to the interstellar medium (determined from Einstein IPC observations) and the optical extinction does not rule out the triple system hypothesis.

8 X-ray Observations of Elliptical Galaxies with Strong Radio Continuum — D. Kim

PR 666-27561

Among the two galaxies to be observed with the ROSAT HRI, NGC1399 have been observed, but NGC1316 is not observed yet. The observational data of NGC1399 have been analyzed and are compared with optical and radio data to investigate the ISM and its relationship with radio jets. We are now preparing a paper.

9 X-ray Emission as a Tool to Study Galaxy Formation: The Case of MS 111.9-3754 - A. Wolter

PR 666-27552

No data received.

10 Cooling Flows in Poor Clusters of Galaxies — L. David

PR 666-27555

We have used ROSAT PSPC observations of several cool clusters of galaxies to determine the distribution of gravitating mass in these systems. By combining the x-ray data with optical observations, we have determined many fundamental properties to groups and clusters (e.g., the distribution and abundance of dark matter, the baryon mass fraction, and the mass-to-light ratio). We are presently extracting more ROSAT observations of clusters of galaxies in order to determine how these fundamental parameters vary between galaxies, groups, and clusters.

11 X-ray Luminosity Functions for O-Type Stars — F.R. Harn- den, Jr.

PR 666-27559

No new data.

A PREPRINTS